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# Integrating Army Test and Simulation: A Window of Opportunity for Tomorrow

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*The U.S. Army test and evaluation (T&E) community is facing a window of opportunity to embark on a reasoned, disciplined, deliberate course of change to achieve greater leverage of modeling and simulation (M&S) technologies. This, in turn, will lead to modernized equipment that best serves the soldier. Currently, the development and operational test communities rely, to a significant extent, on M&S to help design and prepare for tests; to address evaluation where safety becomes an issue; to identify the right types of test data to collect; to reduce costs associated with live testing; and to conduct other numerous tasks. Tomorrow, however, the test community will play an increasing and ever-present role in modernization efforts, using M&S as the medium in which to conduct many of its activities.*

Testers are very good at asking the questions and finding the answers that lead to system improvement. Both industry and government agencies are stretching the envelope in the use of modeling and simulation (M&S) to support test and evaluation (T&E). The National Aeronautics and Space Administration (NASA), for example, routinely relies on M&S to assist in system design, training and even problem solving. Testers can adopt this approach in evaluating concepts for future systems, systems currently in development and systems already fielded. The commercial arena is developing sophisticated physics-based models and simulations that allow ample opportunity to test evolving designs in all types of environments and conditions. The Army T&E community needs to identify and adopt those best practices from other government agencies and industry so that it can provide the independent assessment needed to ensure effective and suitable systems for soldiers.

The Army has initiated an endeavor known as Simulation and Modeling for Acquisition, Requirements and Training (SMART). This effort is the Army's execution of the Office of the Secretary of Defense vision of Simulation-Based Acquisition. SMART is predominantly about leveraging M&S to achieve the integration necessary among the requirements, acquisition and training communities to address system development, total ownership costs and training. What the T&E communi-

ty brings to this integration is the ability to assess the interactions among the system's attributes, as well as how they impact system performance and the soldier's ability to maximize the system's effectiveness.

To truly glean the most from T&E in the modernization process of the future, two things must change. First and foremost is a subtle shift that needs to take place in the relationship between the T&E community, system developers and users. The relationship needed for a successful future is one in which testers, builders and users see each other as full partners in achieving the same goal. This does not mean, however, that testers must give up their ability to independently assess a system's effectiveness. It means that testers and evaluators are uniquely positioned to provide the difficult-to-acquire insights that lead to better decision-making necessary for fielding effective systems.

Second, testers can exploit M&S to a greater extent than ever before, and the Army needs to capitalize on their expertise all the way from concept exploration through system retirement. Because hardware does not exist during concept exploration, or during the early stages of system design, many people may be tempted to insist there is no role for testers until later in the life cycle. This is where M&S comes into the equation and remains present throughout. Those probing questions the Army requires testers to ask can be addressed through system stimulation, system emulation and virtual prototypes.

T&E in partnership from the beginning

The relationship between the Federal Aviation Administration (FAA) and the Boeing Company during the development of the 777 aircraft (*Figure 1*) provides a good model for the type of relationship the Army needs to foster between the T&E community, system developers and users. If the Army is to modernize its systems in a timely and affordable manner, it should heed the lessons learned from the 777 experience. The 777 story is widely known for its application of digital M&S technology to development and production of the new aircraft design. Another important aspect of this story, however, is how this technology facilitated the necessary relationships between Boeing, the FAA and the kickoff customer.



*Figure 1. Assembly of first Boeing 777 First Aircraft*

Boeing was dependent upon the FAA's timely certification of its aircraft design in order to meet the kickoff customer's needs. Boeing adopted the strategy of involving the FAA early in the development process. According to FAA Administrator David Hinson, "The FAA was involved more deeply and directly in every phase of the certification. We were also involved earlier in the design phase, at Boeing's request, and we can see in hindsight that it paid enormous dividends." The dividends Hinson referred to include two aviation milestones: the most comprehensive test program in commercial aviation history; and, for the first time, full approval for extended-range, twin-engine operations (ETOPS) before going into service. This approval normally is not granted until a jetliner demonstrates proven reliability in at least two years of revenue service as established by regulatory guidelines.<sup>1</sup>

Two conditions were required to accomplish these feats. First, Boeing needed to establish, up front and early, its developmental test requirements to verify the aircraft design and system performance. Second, Boeing and the FAA had to collectively refine the flight test program that would lead to all FAA certifications, including the ETOPS prior to actual revenue

service. Refining the certification test program meant that the FAA became a full participant in the 777 test program.

Boeing's developmental testing included 6,122 hours of tests and validation in the Integrated Aircraft Systems Laboratory, which allowed test engineers to "find and fix" problems in the laboratory instead of on the airplane itself. This approach enabled Boeing to save time, eliminate rework and ease the transition into flight testing and commercial service. Previous aircraft development programs at Boeing did not involve fully integrated performance evaluations until ground testing began on the actual airplane.<sup>2</sup>

When Boeing actually initiated live flight tests, the maiden voyage lasted three and a half hours and consisted of cycling landing gear, engine shut down and re-light, as well as other tests that normally never would be conducted on a prototype aircraft's first flight. Such live tests most often would come well into the test plan after many, many hours of previous flight.<sup>3</sup> By addressing test issues from the beginning, and by working in partnership with independent evaluators such as the FAA, Boeing was able to achieve more comprehensive testing, gain greater returns in both data collection and certification from live testing and, in the end, deliver a product that completely satisfied its customer.

A prevalent myth is the assumption that greater use of M&S in a development program implies less need for testing and therefore less need for testers. The 777 experience reveals just the opposite. The 777 aircraft is one of the most tested aircraft in the skies. What M&S did for Boeing and can do for testers in the 21st century is to facilitate the partnering that needs to take place between design engineers, production engineers, test engineers, operational testers, evaluators and users. The 777 has been in service since 1995, and according to the FAA's Hinson, "The 777 has demonstrated repeatedly, and beyond question, that it is safe and airworthy." Although the FAA was intimately involved in the 777 development program, it did not jeopardize its role as an independent evaluator—and ultimately, between both the FAA and Boeing—a worthy system was placed into service.

This type of partnership, prevalent in Army system development, is what will ensure the Army's successful implementation of SMART. Testers are key to establishing the validity of virtual prototypes, stimulators, emulators and simulators, so that they can be used to safely stress proposed system designs over and over again, gaining greater and greater insight. Once validated and accredited virtual prototypes and other systems are available, it becomes easier and more efficient to assess and evaluate system upgrades and modifications from a suitability and effectiveness point of view.

The tester's role in this partnership of tomorrow is twofold. Developmental testers and operational testers can anticipate the types of testing that will be required to prove out designs and system operational performance. If the testers challenge system designers with these types of questions and considerations early on, designers are more likely to propose design concepts that will better meet soldiers' needs. An effective and efficient way to achieve this goal is through a set of M&S tools that can be shared by both the designer and the tester. This, in turn, highlights the tester's other role. In designing test plans, scenarios, data collection schema and so forth, testers can collect data that not only feed the evaluation process, but also that lay the groundwork for M&S tool modification and development. This provides a greater set of capabilities that can be exploited in developing the next variant or modification of the system.

Simulation's value to both the designer and the tester lies in its ability to address detail complexity, which arises from multiple components; and to address dynamic complexity, which arises from cause-and-effect relationships with regard to time and space. Using simulations and virtual prototypes as a test medium, testers can ask the tough questions during the phase of system development when design changes are less expensive to make. As a result, evaluators have at their disposal the means to explore the interactions among design, system performance, manufacturability, cost, doctrine, tactics, techniques and procedures; to assess the implications of these interactions; and to provide the information to be weighed in deciding the best course of action for system development.

### System test and development in a synthetic environment

The Boeing Aircraft Company has helped testers use digital technology to facilitate a partnership between system developers and testers. In addition, more and more government agencies, such as NASA, are increasing their use of M&S to support T&E, and the Army can benefit from their successes and experiences. NASA's reliance on M&S most notably comes into play when the space agency prepares for a mission. Because astronauts in space have only limited resources and options at their disposal to handle unexpected situations, NASA simulates every possible scenario conceivable and uses simulations to help develop solutions.

One of the most ambitious and risky human endeavors ever is the development of the International Space Station (ISS). The ISS (*Figure 2*) involves governments and companies from these 16 countries: the United States, Russia, Japan, Canada,

the United Kingdom, Belgium, Denmark, France, Germany, Sweden, Norway, Spain, Brazil, Switzerland and the Netherlands. NASA's role in the ISS encompasses 45 shuttle missions to assemble 100-plus elements composed of 460 tons of structures, modules, equipment and supplies. This is collaboration on an unprecedented scale, and T&E is right smack in the middle of it. Because the ISS exists and operates in space, the harshest environment known to humans, T&E is super critical. Even more critical, however, is the role of simulation in T&E. NASA does not have the ability to test live, therefore it must rely on simulations of the space environment and on virtual prototypes of systems being deployed.

The ISS represents one of the most advanced integrations of different simulations and models into a single environment. NASA accomplished this task through the Multidimensional User-oriented Synthetic Environment (muSE) software system, developed by MUSE Technologies, Incorporated. NASA engineers and MUSE programmers worked to combine three-dimensional ISS engineering models, orbital operations analysis capabilities, scientific payload models and a highly accurate solar system simulation into a single integrated model.

The fusion of analytic capability provides the means for simulating orbital motion, flight dynamics, payload performance and human factors in a variety of operational conditions likely to be encountered in space. The muSE environment facilitates the interoperability of all the existing analysis modules so that complex system and orbital environment interactions can be understood and assessed in preparation for system deployment and actual missions. This capability is planned for use in most of NASA's future endeavors with regard to designing, planning and operating the ISS.<sup>4</sup>

The implications for T&E in the future are significant when one considers what NASA has accomplished in its bid to help build the ISS thus far. Developmental and operational testing is, by necessity, being conducted

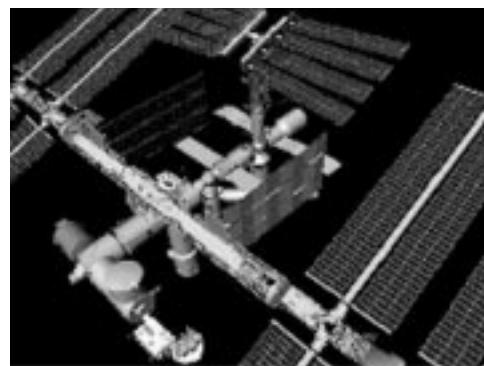


Figure 2. Computer-aided design rendering of the International Space Station

in a synthetic environment. Even more significant is the fact that this is all being conducted in a collaborative manner across international boundaries and time zones. Technology now exists to realistically re-create an environment; to place engineering-level models of complex systems in that environment; and to conduct sophisticated analysis. This analysis not only leads to critical system design decisions and operational considerations, but it also influences mission training rehearsals as well.

This new technological approach significantly enhances the T&E community's future by overcoming the past constraints of cost, safety considerations and scheduling of test assets and ranges. These constraints often have shaped the course of current testing. In the 21st century, when conducting operational tests, the Army no longer will need to pull soldiers away from their duty stations to participate in the test. Rather, simulation technology can bring the operational test literally to a soldier's workstation, regardless of what part of the globe and in what time zone the soldier is stationed. Additionally, the operational test can involve numerous soldiers who are geographically distributed, interacting with simulated forces and equipment.

It may be tempting to dismiss this proposed scenario as wishful thinking, but again, NASA stands as a testament that it really is not that far off in the future. The ISS effort is being conducted such that NASA scientists in geographically distributed locations work collaboratively and individually on specific problems associated with ISS development. Using network collaboration software and interactive devices, engineers at NASA's Langley Research Center in Virginia can conduct simulations in collaboration with engineers at the John C. Stennis Space Center in Mississippi.

Simulation fidelity is very much a part of these collaborations. According to Michelle Garn, lead on the ISS Immersive Accommodation Environment at Langley Research Center, "The immersive environment allows us to tie analytical capability together, to look at codes from multiple disciplines across the country. Everyone can get into the environment and see how their data affect another engineer's operation and whether or not the operation will work." The immersive environment at Langley realistically and accurately portrays the ISS moving in the right orbit around the Earth at the correct speed and altitude, and it includes temperature extremes, light, shadows and so forth, all built using articulated computer-aided design (CAD) models operating in four dimensions, including time.<sup>5</sup>

The proof of the fidelity and accuracy of NASA's simulations lies in the very existence of the ISS that orbits the earth today. LTC Nancy Currie, Army astronaut, can attest to this personally. She had the honor and tremendous responsibility of operating the

Canadian-built robotic arm to dock the U.S. *Unity* to the already orbiting Russian-built *Zarya* during Space Shuttle Mission STS-88, the first ISS assembly mission. LTC Currie had only one chance to complete the mission successfully, and she had the added challenge of operating with only one and a half inches of clearance on either side of the *Unity* as it egressed from the shuttle payload bay.

To prepare for this mission, LTC Currie had no option other than to develop robotic arm operating techniques and to train using a simulator. After successful mission completion in December 1998, she reported to NASA engineers that the simulations she used in mission preparation looked and felt like the real thing, and she could tell no difference. That is quite impressive in view of the fact that docking the two ISS components had to occur using optical alignment in an environment of extreme light and shadows while orbiting at a speed of 17,000 miles per hour.<sup>6</sup>

#### A special consideration for operational testing

A look at Army system development to date reveals that developers build systems to overcome operational deficiencies by designing against an operational requirements document. Typically, in the system development life cycle, years pass before operational testing takes place, and soldiers who participate in the testing are seeing the system for the first time. They have had no previous opportunity to develop the tactics, techniques and procedures to successfully exploit the system's new capability.

Today, because of virtual prototypes, soldiers and testers can evaluate human factors engineering and performance much earlier in the system development cycle. The implication is that system design changes can be made to accommodate optimized tactics at a time when it is less costly. This can be extended to collective training so that tactics and crew proficiencies in a combined arms environment can be achieved from a system-of-systems perspective before a commitment to hardware is required.

The Comanche next-generation helicopter program already is using this approach to train test pilots and to evaluate system development. Plans are underway to extend into collective training using the Comanche Mission Simulator (*Figure 3*).<sup>7</sup> With the Comanche program, the Army is taking initial steps toward capitalizing on the opportunity for operational evaluations to begin as new concepts are developed.

A remaining challenge for the Army is the lash up between the T&E community and how to assess system effectiveness in light of system supportability. Adequate M&S tools do not yet exist to allow the trade-offs that

must occur in system development in order to ensure affordable performance. The T&E community must work closely with the analytic and logistics communities to assist in developing physics of failure modeling and consumption (that is, fuel and munitions) prediction. Having supportability analysis data available to testers and evaluators results in a more rigorous and complete understanding of system effectiveness and suitability.



Figure 3. Comanche simulator used to train test pilots

Another area in which operational testing could benefit from future M&S is the fatigue and human dimension aspects of battlefield operational performance. Here too, the Army is taking an initial step toward capitalizing on developing technology. The Army is teaming with the University of Southern California (USC) in a university-affiliated research center, designated as the Institute for Creative Technology (ICT). Through USC, the Army can tap into the creative talents of the entertainment industry and the evolving technologies being developed at the university. By combining these capabilities with scenarios that depict the rigors and demands of battle, the ICT can create simulations that have the look and feel of a real battlefield.

When this level of capability is achieved, testers can provide better insights into system designs and their effectiveness and suitability in the environment for which the system actually was intended. Systems can truly be tested for whether the man/machine interface really enables a soldier immersed in the "fog [and stress] of war" to operate and perform at maximum capacity. For the first time, the partnership between testers, builders and users will result in a system maximized for performance and supportability under the very real stress of battle.

A point to ponder for future T&E

By examining events occurring both in industry and in government agencies, and then by adopting those

practices, Army T&E is poised to play a more significant, integrated role in fielding effective systems. M&S provides a means of facilitating the ways in which future T&E will be conducted. T&E is reliant on such tools today, and it will, by necessity, continue to exploit the capacity of M&S. As systems become more complex and increasingly reliant on software, simulation becomes the only practical and effective means through which to test and evaluate.

The Boeing 777 contains more than two million lines of code in its avionics and entertainment systems. The ISS already (with only two components assembled) has 1.7 million lines of code in its flight support software that includes test control and simulation software. In addition, 400,000 lines of code are embedded in its 16 computers that are responsible for communication with 2,000 sensors.<sup>8</sup> Given that systems today are flown, loaded and powered by software that drives actuators, valves and more, the question arises as to what is actually being tested. Software embedded in systems defines how the system operates and thus must replicate the system's performance, because it is itself a simulation. What is being tested, therefore, is how well the simulation replicates the physical environment. The future challenge for testers, then, is how to extend this concept to evaluating system performance by evaluating the simulation.

#### A final note

The information age continues to serve up newer and more exciting methods for enhancing testing and development. This will require the T&E community's continuous involvement early on in system development to ensure that the needs of 21st century battlefield are met. Soldiers may find themselves in the same situation as today's astronauts, in that they will go into battle for the first time with systems that they have trained on only through simulation. These soldiers will count on the T&E community to ensure that those systems will be suitable and effective...a trust held sacred by Army T&E. □

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## Endnotes

<sup>1</sup>Gary Vassallo, "ETOPS Validation 1,000 Cycles," *Airliner*, July-September 1995, pp. 10-14.

<sup>2</sup>Jeff Hawk, "777 Certification," *Airliner*, July-September 1995, pp. 6-9.

<sup>3</sup>Karl Sabbagh, producer/director, "21st Century Jet, the Building of the 777: Taking Flight," PBS Video, 1996.

<sup>4</sup>Steve Sukman, "NASA Orbits International Space Station in muSE Synthetic Environment," MUSE Technologies Press Release, July 15, 1998.

<sup>5</sup>Janet Gould, "Space Age Simulations: Tools for Engineering the International Space Station," *Desktop Engineering*, April 1999.

<sup>6</sup>Interview with LTC Nancy Currie, USA, Johnson Space Center, Houston, Texas, September 3, 1999.

<sup>7</sup>"Comanche Modeling, Simulation and Training Development," Program Management Office White Paper, June 1999.

<sup>8</sup>"International Space Station Facts," Boeing Press Release, 1999.

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